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Narrow-band f.m. system for television links: interference between f.m. and a.m. television signals

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NARROW-BAND F.M. SYSTEM FOR TELEVISION LINKS: INTERFERENCE BETWEEN F.M. AND A.M. TELEVISION SIGNALS.

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Summary

The Band V f.m. television links used for television outside broadcasts have suffered more and more from interference as the network of u.h.f. television broadcasting transmitters has expanded. There is also thought to be an increasing danger that Band V links will cause interference to broadcast television reception. Experimental work has been carried out to determine whether reducing the bandwidth of the links can reduce the problem of mutual interference between the links and the broadcasting services in adjacent channels in Band V.

The conclusions drawn from this work are that the adoption of a narrow-band v.s.b. system could reduce adjacent-channel interference.

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1. Introduction

The Band V television links which are used in outside broadcasts for fixed and mobile applications use frequency-modulation (f.m.) with peak-to-peak deviation of 4 MHz,* occupying a bandwidth of 16 MHz. There thus appears to be a requirement for two, unused, adjacent 8 MHz television channels at any site where these links may be required to operate. It has been found in practice, however, that the link is very sensitive to interference from broadcast television signals in the adjacent channels, so that it is unwise to rely on the use of a Band V f.m. link in any situation where four consecutive clear channels are not available.

Expansion of the u.h.f. broadcasting network has made it increasingly difficult to find four such adjacent channels in which to operate an f.m. television link. Furthermore, the risk that link transmitters will cause interference to broadcast reception may have to be considered where small communities are served by low-power relay stations. At present, the links employ very low transmitter-powers, of the order of one or two watts, and these are unlikely to have a very extensive field of interference. But when higher powers become available for the link equipment, interference with broadcast reception might well become significant.

Earlier work[1] on narrow-band f.m. television has shown that it is possible, using vestigial-sideband techniques, to restrict the bandwidth of the links to 8 MHz (i.e. to the bandwidth provided for a single u.h.f. broadcast channel) while continuing to use a deviation of 4 MHz peak-to-peak. The consequences to the link of this bandwidth restriction are to reduce slightly the linearity and signal-to-noise ratio of the video signal. An experimental model gave 4% differential gain and 3·5° differential phase distortion of the colour subcarrier (compared with 2% and 1·5° for the full-bandwidth system) and suffered 1 dB reduction of signal-to-noise ratio relative to the full-bandwidth system. Although the narrow-band system cannot accommodate the usual 7·5 MHz f.m. sound subcarrier which is added to the video signal before transmission, it was found possible to incorporate a subcarrier at 6 MHz for this purpose.

In order to establish to what extent the use of the narrow-band f.m. technique could give reduced interference, as compared with the full-bandwidth system, a number of tests were conducted on both systems. Standard 70 MHz f.m. link modulator and demodulator units were used for the tests, with filters to restrict the bandwidth to 16 MHz or 8 MHz for conventional full-bandwidth (double-sideband) or narrow-band (vestigial-sideband) operation, respectively. Each filter consisted of 6 low pass sections and 5 high pass sections to give a bandpass response. The filter characteristics are shown in Fig. 1.

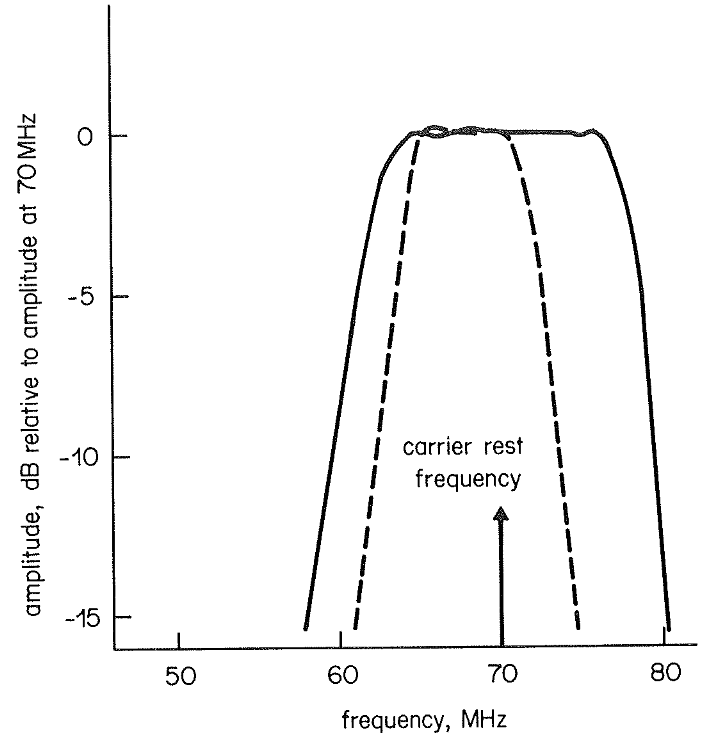

Fig. 1 - Amplitude/frequency response characteristics of the 70 MHz bandpass filters

The effect of restricting the bandwidth of the f.m. signal can be best described with reference to Fig. 2 which shows, diagrammatically, the frequency ranges covered by various narrow-band f.m. television systems in relation to conventional a.m. broadcast channels. Two u.h.f. a.m. broadcast television signals are shown at (*a*), with the vision and sound carrier frequencies indicated within the channels. A conventional (d.s.b.) f.m. television signal is shown at (*b*). The modulation polarity throughout is such that the frequency-deviation corresponding to white-level is negative. The central shaded area indicates the part of the spectrum occupied by the lower-frequency sidebands, for which the modulation index is greater than unity, this region extends over 4 MHz, the peak-to-peak deviation used. At (*c*) the effect of the narrower filter upon the f.m. signal is shown. The lower-frequency sidebands are retained intact, together with sidebands extending a further 4 MHz away on the low frequency side only of the carrier rest frequency.

The passband of the signal is thus restricted to 8 MHz, and a system operating with such a filter has been shown to be feasible.[1]

Although restriction of the link operating bandwidth should give some useful improvement in respect to interference without any change of link frequency, it is clear

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* In situations where signal-to-noise ratio is inadequate, the deviation can be increased to 8 MHz peak-to-peak, but there is then a reduction in the linearity of the link.

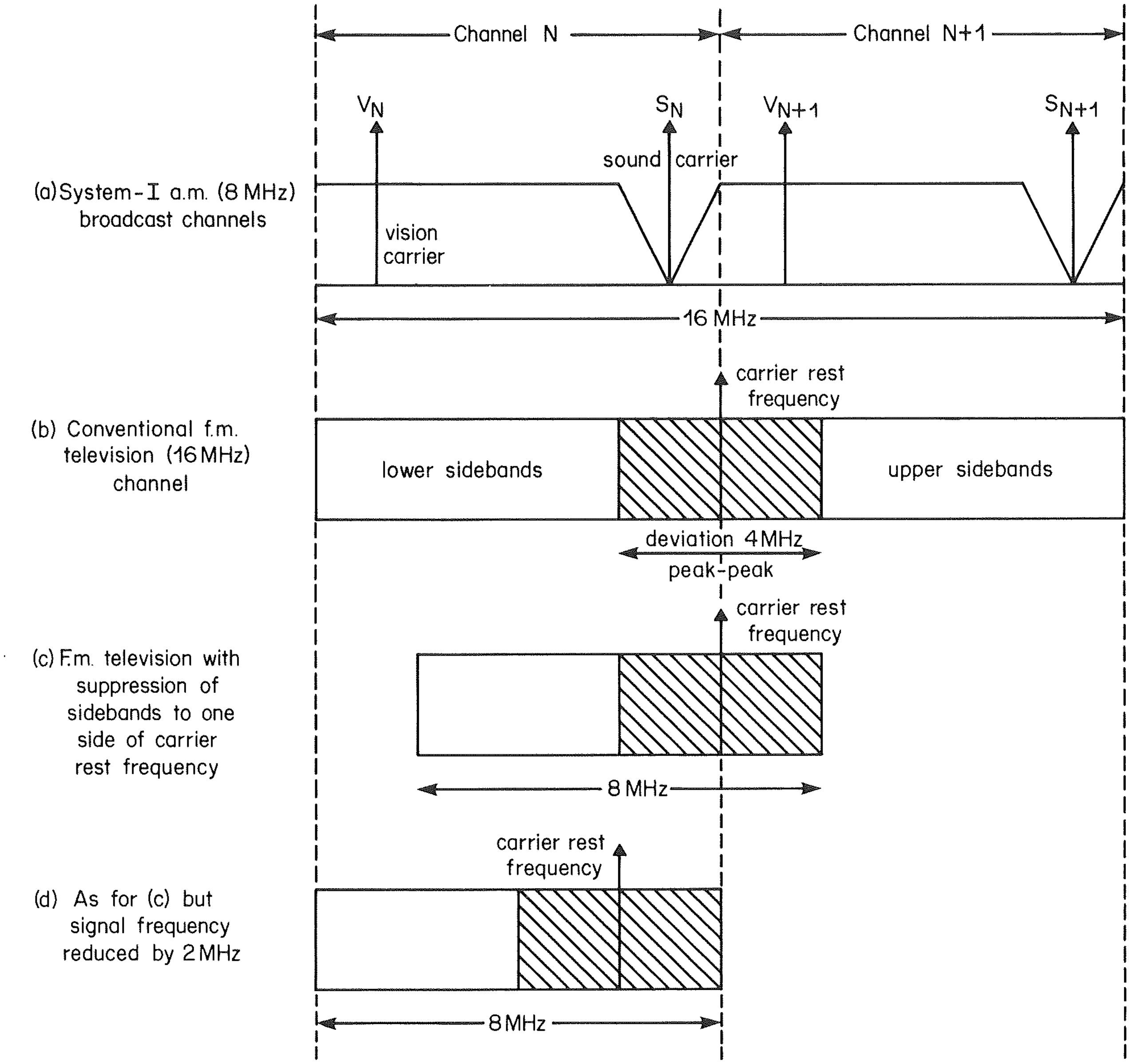
Channel N
Channel N+1
V_N
S_N
V_{N+1}
S_{N+1}
sound carrier
(a) System-I a.m. (8 MHz) broadcast channels
vision carrier
16 MHz
carrier rest frequency
(b) Conventional f.m. television (16 MHz) channel
lower sidebands
upper sidebands
deviation 4 MHz peak-peak
carrier rest frequency
(c) F.m. television with suppression of sidebands to one side of carrier rest frequency
8 MHz
carrier rest frequency
(d) As for (c) but signal frequency reduced by 2 MHz
8 MHz

Fig. 2 - Diagrammatic representation of bandwidth occupied by f.m. and a.m. television signals.

from (c) that the link is partly occupying two channels. It was thought possible that some extra benefit might be obtained by adjusting the operating frequency so that the passband corresponded to one 8 MHz broadcast channel as at (d).

The interference tests were arranged to cover the full-bandwidth f.m. link and both cases of the vestigial-sideband link (i.e. using the same carrier rest frequency moved 2 MHz in order to accommodate the signal in one 8 MHz broadcast television channel - case (d)). In addition, an alternative form of the narrow-band system was investigated in which the vestigial sideband lay below the carrier rest frequency.

2. Interference from system I a.m. television signals to f.m. television signals

2.1 Experimental arrangement

A block schematic diagram of the experimental arrangement used for the tests with interference to f.m. television signals from a.m. signals is shown in Fig. 3. Both the f.m. modulator and demodulator operated at a carrier rest frequency of 70 MHz and so the interfering a.m. signal was subjected to a double frequency-changing process in order to produce the necessary signals for co-channel and adjacent-channel interference to the f.m. system working at 70 MHz.

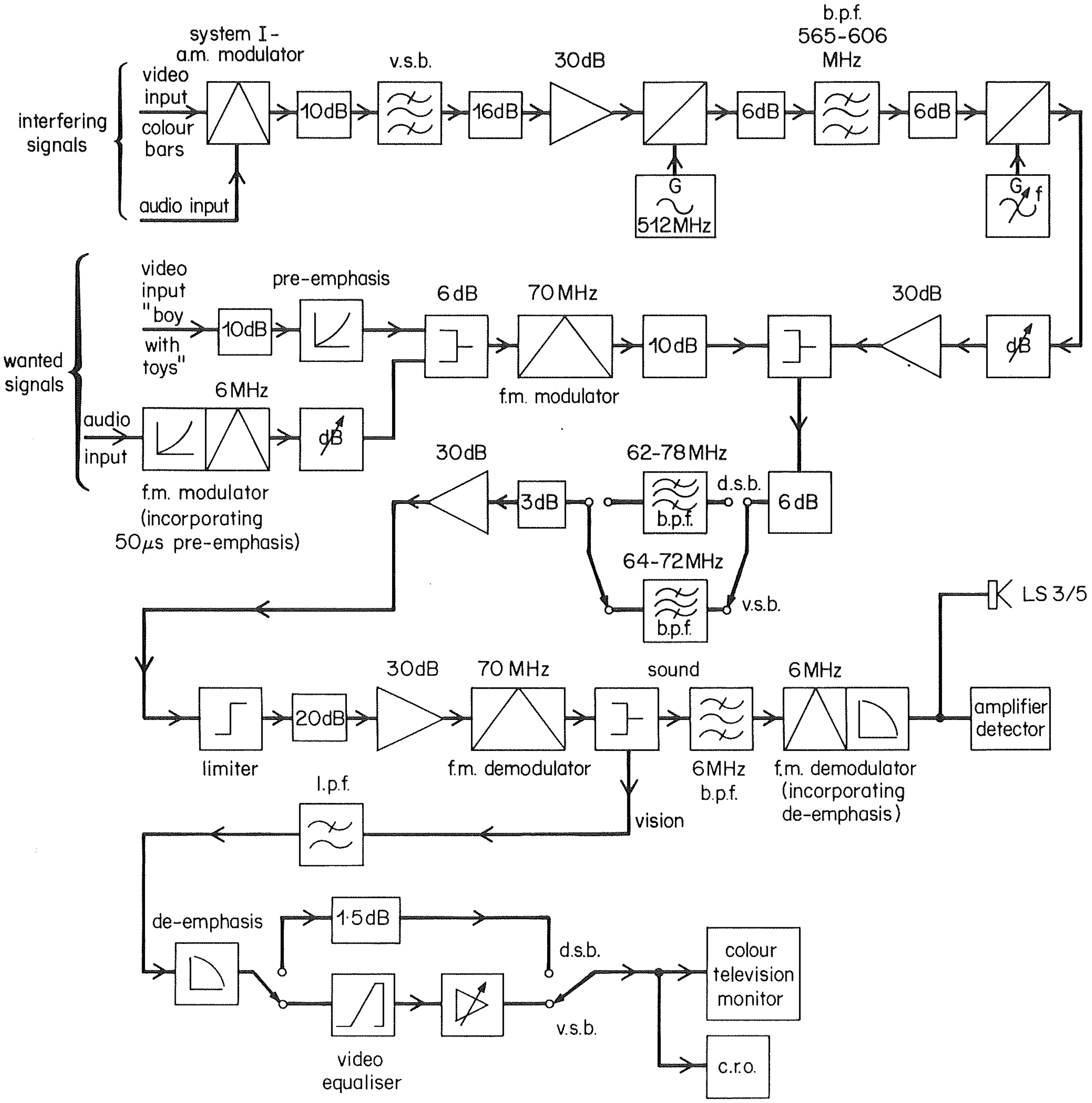

Fig. 3 - Experimental arrangement for interference to f.m. from a.m.

2.2. Description of tests

The tests were conducted using the full-bandwidth (d.s.b.) filter and then the narrow-bandwidth (v.s.b.) filter to control the bandwidth of the f.m. signal. The interfering (a.m.) signals were added to the wanted (f.m.) signals prior to the filter, and the demodulated video signal from the f.m. demodulator was fed to a colour picture monitor. Colour bars were used for the interfering video signal because they have in the past been found to provide a particularly severe form of interference. The colour slide 'boy with toys' which is shown in Fig. 4 (in monochrome) was used for the wanted signal. The frequency of the interfering signal was adjusted so that co-channel and adjacent-channel interference conditions could be reproduced.

For all the tests, the interference to pictures was assessed subjectively by two members of the technical staff. The level of the interfering signal was adjusted, in each case, to give an impairment judged to be 'just perceptible' and the protection ratio (the ratio between the level of the wanted signal and the level of the unwanted signal) was noted. Signal levels were measured with a spectrum analyser and, in the case of the a.m. signal, the level measured was that of the vision carrier at its peak value (i.e. during the sync pulse).

Five tests were conducted to determine protection ratios for 'just perceptible' interference to the picture. In the first test, the f.m. system was operated at full-band-

Fig. 4 - Still slide used for tests

width (16 MHz). In the second and third tests, the system was operated in the narrow-band condition (8 MHz bandwidth), but occupying parts of two broadcast channels (as at (*c*) in Fig. 2). In the fourth and fifth tests, the system was operated in the narrow-band condition in one broadcast channel (as at (*d*) in Fig. 2). All the different conditions were obtained by setting the second local-oscillator in the frequency-changing process to put the interfering signal at the appropriate frequency. In the third and fifth tests, the frequency-changing process was arranged to invert the spectrum of the interfering signal so that the f.m. system under test was, as far as the interference properties were concerned, one in which the upper sidebands conveyed the higher-frequency video information. The use of this experimental technique avoided the need to make a second narrow-band filter with characteristics accurately matched to those of the existing filter but tuned to select the upper sidebands of the f.m. signal and reject the lower sideband from 2 MHz below carrier rest frequency.* Fig. 5 illustrated diagrammatically the way in which the interfering signal was tuned in order to reproduce the required interference conditions for the f.m. signal (which had a fixed rest frequency).

For all of the tests involving impairment to the picture, the effect upon protection ratio of introducing a 6 MHz sound subcarrier was examined, as there is a requirement for a sound channel in many of the applications for Band V links. The peak-to-peak amplitude of the sound subcarrier was 14 dB below that of the video signal, (this is the same level as that used for the 7·5 MHz subcarrier in the existing link equipment).

The tests on the d.s.b. system and the four different conditions of the v.s.b. system were repeated with a 6 MHz f.m. sound subcarrier added to the video signal before modulation, and with a 6 MHz f.m. demodulator to extract the sound channel from the demodulated video signal. Noice level on the sound channel was measured, in the absence of sound programme, by an amplifier-detector type of millivoltmeter. For the double sideband system a value of 64·5 dB signal-to-noise ratio was measured and for the v.s.b. system the value was 63 dB. Protection ratios were obtained for a sound signal-to-noise ratio of 60 dB (unweighted) at peak deviation.* In the case of the narrow-bandwidth system, this corresponded to a reduction of 3 dB in the signal-to-noise ratio; for the full-bandwidth system the reduction was 4·5 dB.

The protection ratios for 'just perceptible' impairment to the picture are presented in graphical form in Fig. 6; those for 60 dB signal-to-noise ratio in the sound channel are shown in the same form in Fig. 7.

2.3. Discussion of results

During the tests in which protection ratios for 'just perceptible' impairment to the f.m. picture were being determined, at no time was the presence or absence of the 6 MHz sound subcarrier found to make any difference to the result.

Both of the narrow-band systems which operate within two u.h.f. channels (i.e. those for which the carrier rest frequency was at the boundary between two channels) were less sensitive to adjacent-channel interference than the full-bandwidth system. The results indicate that receiving a signal which contains principally lower-sideband information and rejecting the upper-sidebands give a more symmetrical performance in respect of rejection of adjacent-channel interference than receiving the upper sidebands and rejecting the lower-sidebands. Susceptibility of the narrow-band systems to co-channel interference was somewhat higher (2 dB) than for the full-bandwidth system.

The results for narrow-band systems in a single 8 MHz channel show that this arrangement is more sensitive to co-channel interference, and very sensitive to adjacent-channel interference on one side. The protection ratio requirements in the four channels of interest show that improved immunity to interference in channel N + 2 is balanced by an increase in susceptibility to interference in channel N − 1 compared with the narrow-band system operating between channels N and N + 1.

When protection ratios for the sound channel were studied, the results for the full-bandwidth system showed that the protection ratios needed for the 60 dB sound signal-to-noise ratio were very similar to those for 'just perceptible' picture impairment. For the narrow-band system operating between channels N and N + 1, the sound channel appears to be slightly less sensitive to co-channel interference than the picutre, but to have similar sensitivity to adjacent-channel interference. The narrow-band system

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* Subsequent tests using a filter to select the upper sidebands instead of inverting the spectrum of the interfering signal, gave results very close to those obtained in these tests even though the characteristics of the filter used were not particularly closely matched to those of the lower-sideband filter.

* The reason for choosing 60 dB signal-to-noise ratio as the standard for the sound channel was that this corresponded to a 3 dB reduction for the narrow-band system, and could be measured accurately and conveniently in all cases.

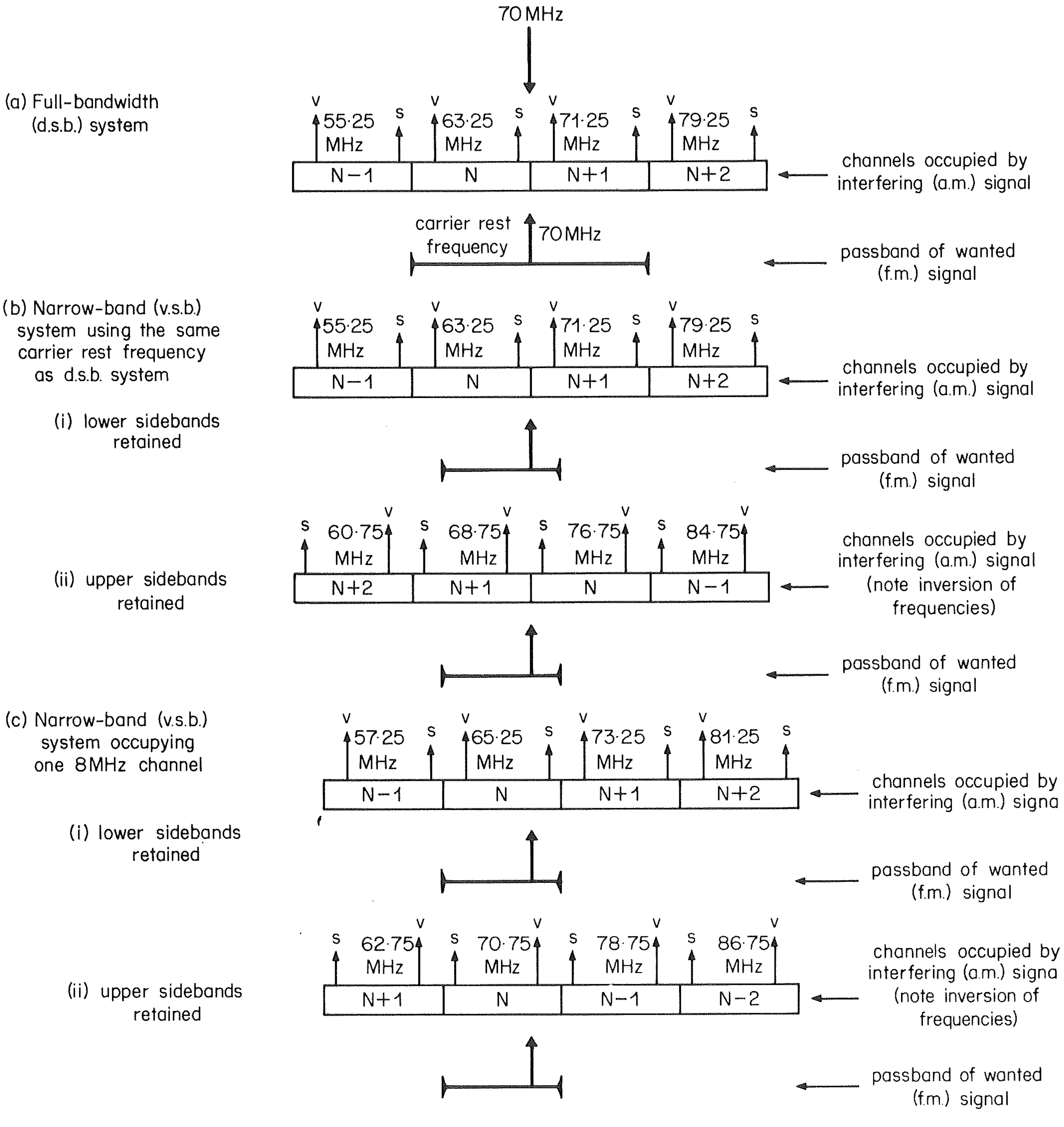
70 MHz
(a) Full-bandwidth (d.s.b.) system
V 55·25 MHz S
V 63·25 MHz S
V 71·25 MHz S
V 79·25 MHz S
N−1
N
N+1
N+2
channels occupied by interfering (a.m.) signal
carrier rest frequency
70 MHz
passband of wanted (f.m.) signal
(b) Narrow-band (v.s.b.) system using the same carrier rest frequency as d.s.b. system
(i) lower sidebands retained
V 55·25 MHz S
V 63·25 MHz S
V 71·25 MHz S
V 79·25 MHz S
N−1
N
N+1
N+2
channels occupied by interfering (a.m.) signal
passband of wanted (f.m.) signal
(ii) upper sidebands retained
S 60·75 MHz V
S 68·75 MHz V
S 76·75 MHz V
S 84·75 MHz V
N+2
N+1
N
N−1
channels occupied by interfering (a.m.) signal (note inversion of frequencies)
passband of wanted (f.m.) signal
(c) Narrow-band (v.s.b.) system occupying one 8 MHz channel
(i) lower sidebands retained
V 57·25 MHz S
V 65·25 MHz S
V 73·25 MHz S
V 81·25 MHz S
N−1
N
N+1
N+2
channels occupied by interfering (a.m.) signa
passband of wanted (f.m.) signal
(ii) upper sidebands retained
S 62·75 MHz V
S 70·75 MHz V
S 78·75 MHz V
S 86·75 MHz V
N+1
N
N−1
N−2
channels occupied by interfering (a.m.) signa (note inversion of frequencies)
passband of wanted (f.m.) signal

Fig. 5 - Diagram illustrating the tuning of the interfering (a.m.) signal relative to the wanted (f.m.) signal at 70 MHz.

operating in a single channel (N) showed a high susceptibility to interference over three channels to such a degree that, under some conditions of adjacent-channel interference, impairment to the sound channel might be quite severe whilst the link would still be capable of carrying reasonably good quality pictures.

3. Interference from f.m. television signals to system I a.m. television signals

3.1 Experimental arrangement

The experimental arrangement used for the tests to

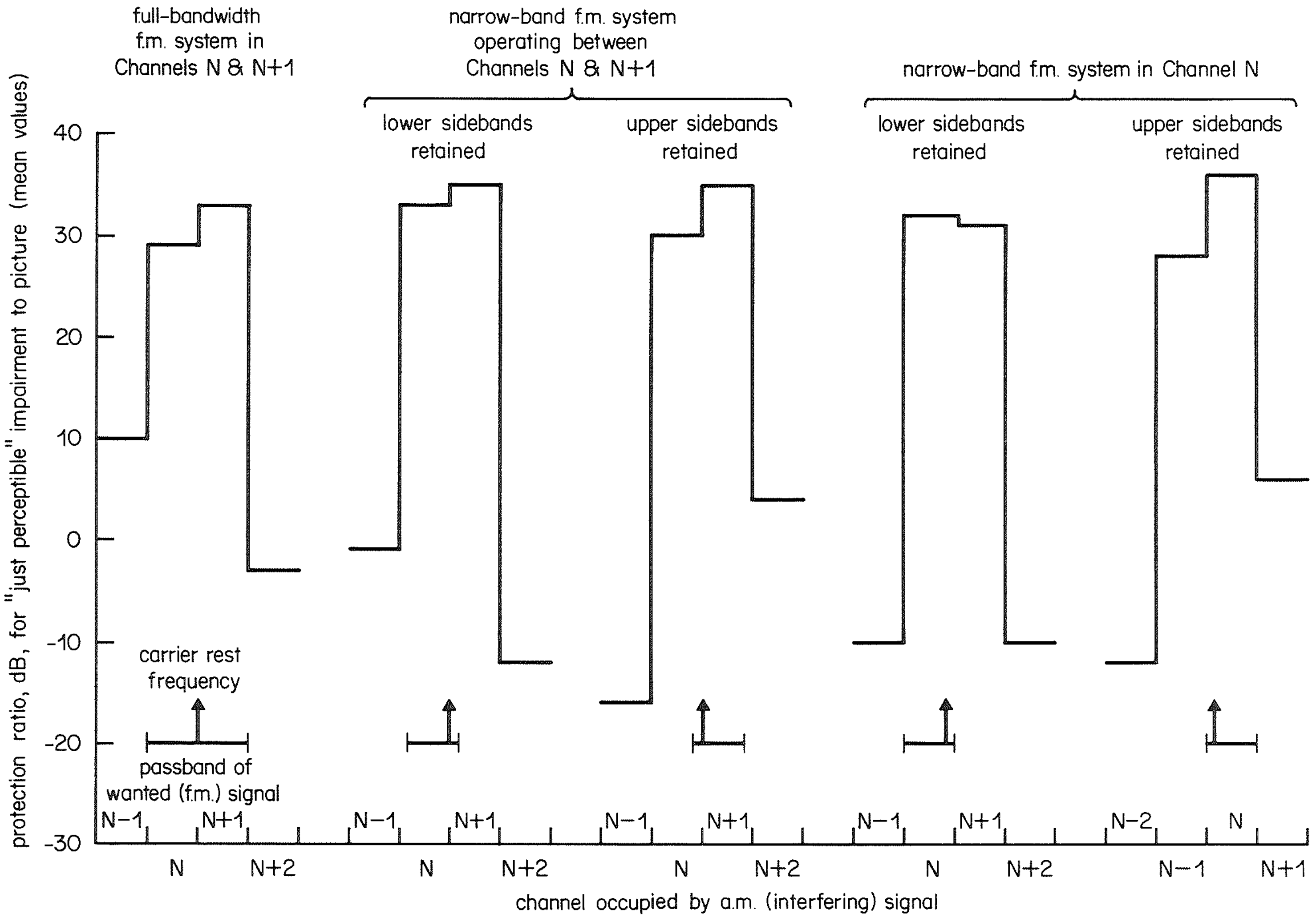

Fig.6 - Protection ratios for f.m. television (vision) signal with interference from a System I a.m. television signal

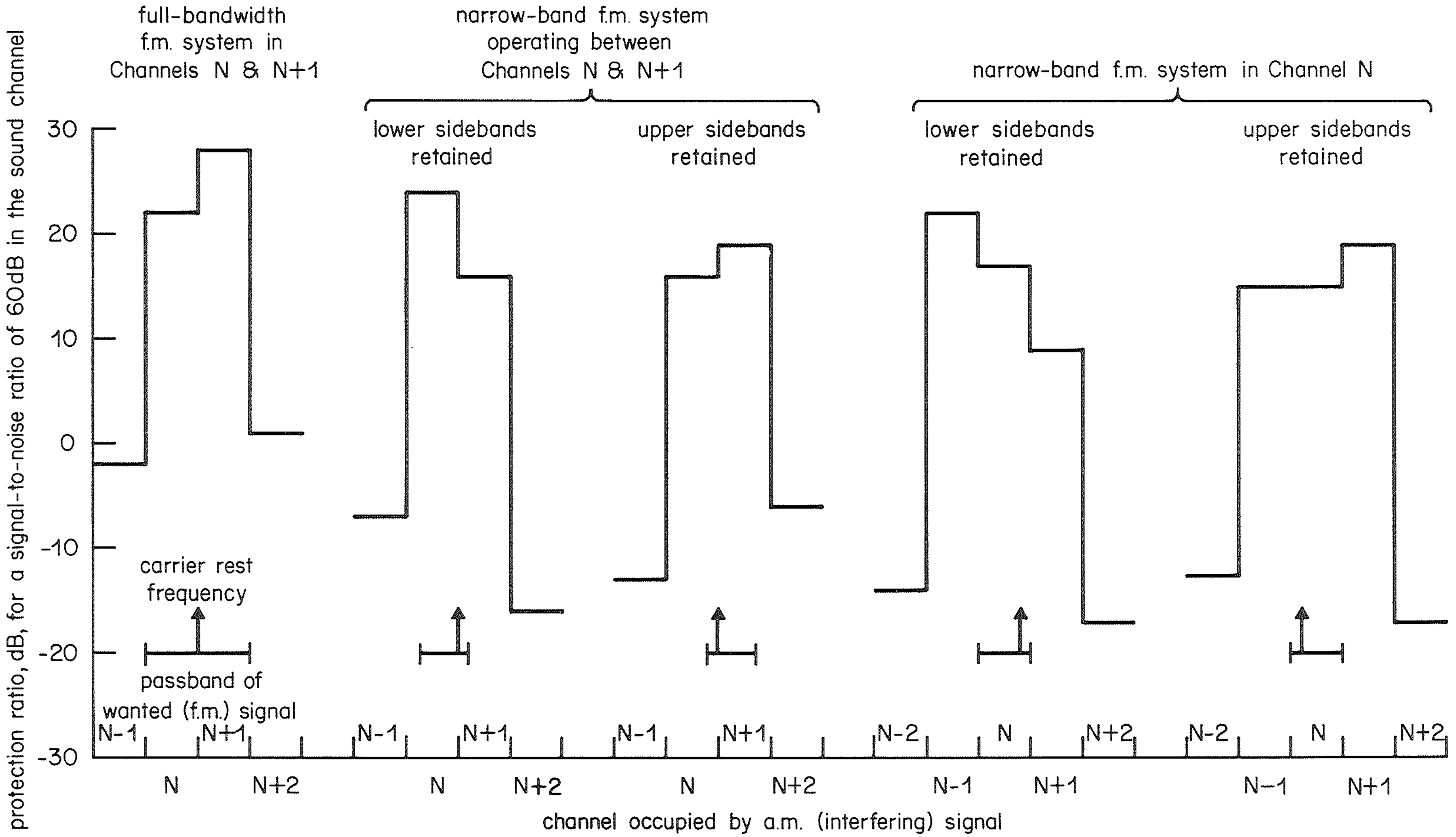

Fig. 7 - Protection ratios for the sound channel of an f.m. television signal with interference from a System I a.m. television signal

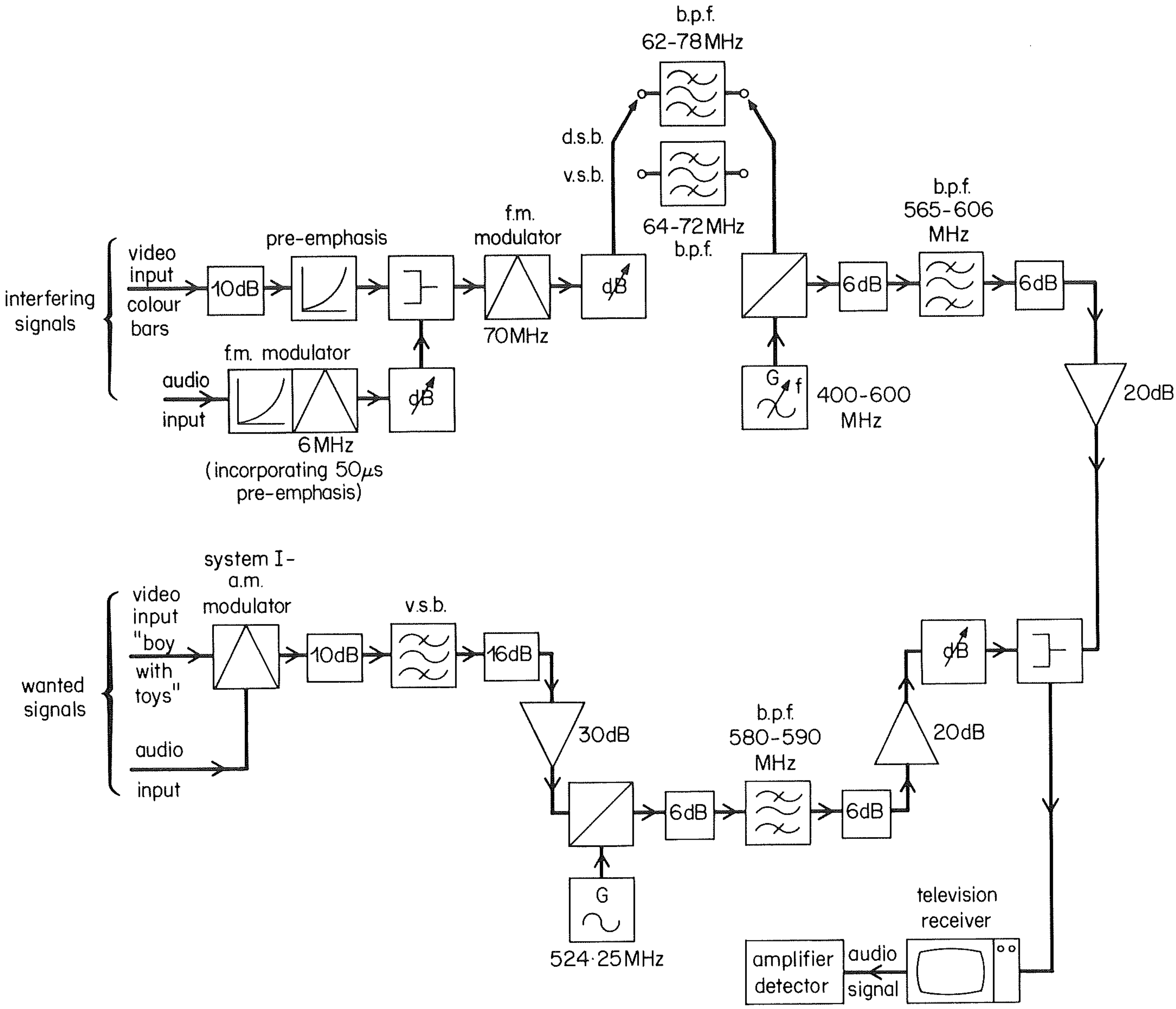

Fig. 8 - Experimental arrangement for interference to a.m. from f.m.

determine protection ratios for domestic reception of u.h.f. broadcasts in the presence of interference from a Band V f.m. link is shown in Fig. 8. In the previous experimental work, the filters for use with the f.m. systems were used to define the band-width of the f.m. system at the input to the limiter so that the benefits to the link of narrow-band operation could be assessed. The arrangement shown in Fig. 8 used the same filters to control the bandwidth of the interfering f.m. link transmitter so that the effect of using a narrow-band f.m. transmitter upon the reception of a.m. signals could be determined.

The wanted (a.m.) signal was generated at an intermediate frequency and converted to u.h.f. for demodulation by a conventional broadcast receiver. The wanted picture ("boy with toys") was displayed by the receiver, and an output was provided from the intercarrier sound demodulator for sound channel measurements. The interfering f.m. signal (colour bars) was converted to u.h.f. after passing through the appropriate filter, and then added to the a.m. signal.

3.2 Description of tests

The picture displayed on the screen of the broadcast receiver was observed, as before, by two members of the technical staff, and the level of the interfering signal was adjusted until the impairment to the picture was judged to be "just perceptible". Interfering f.m. signals with and without a 6 MHz sound subcarrier were used. Full-bandwidth (d.s.b.) and narrow-band (v.s.b.) f.m. signals were used and, as in the previous tests, the narrow-band f.m. system was tried alternately with upper sidebands suppressed and then with lower sidebands suppressed. Narrow-band f.m. signals were used in both the signal-channel arrangement and with the system operating between-

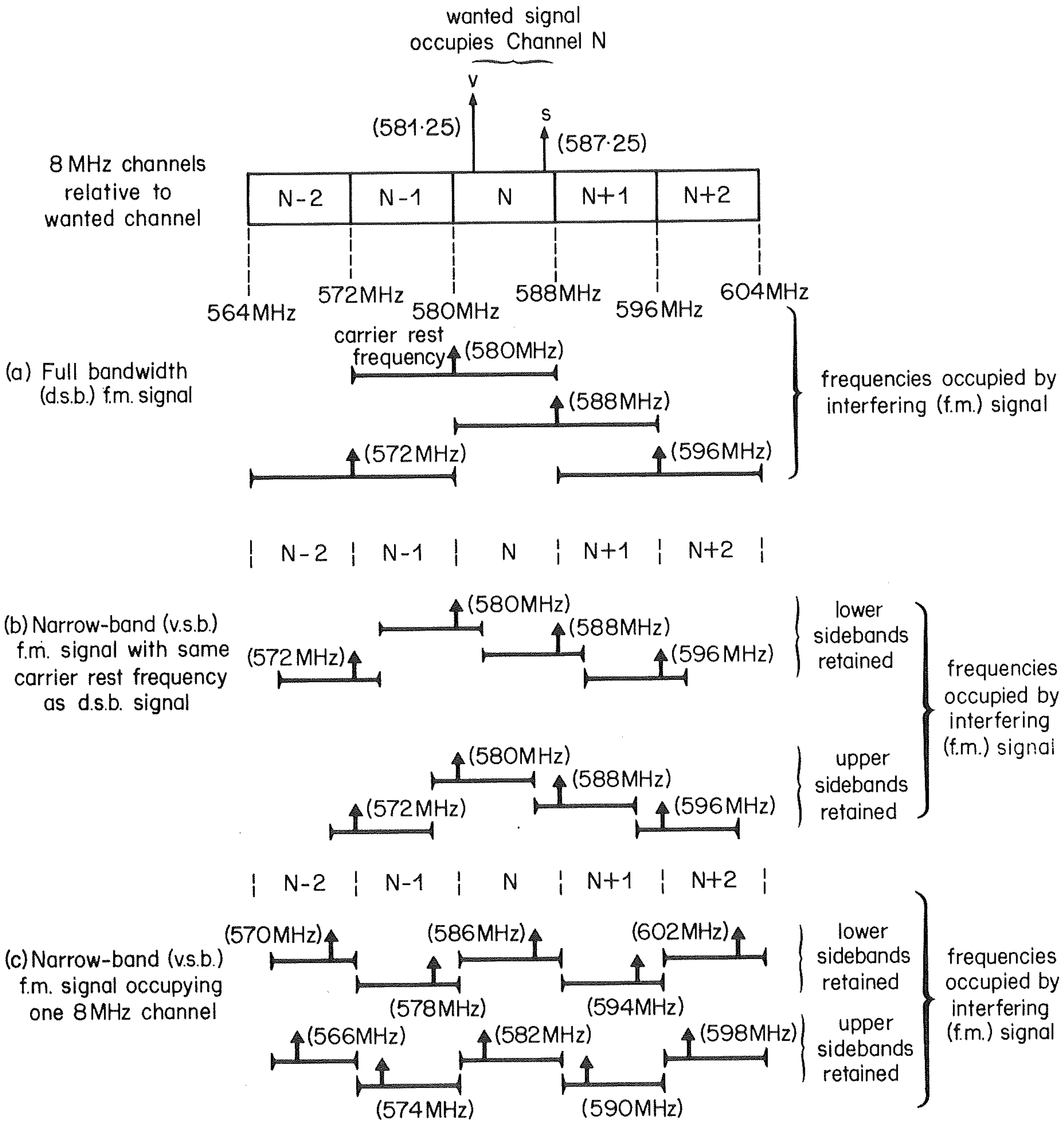
wanted signal occupies Channel N
V
(581·25)
S
(587·25)
8 MHz channels relative to wanted channel
N-2
N-1
N
N+1
N+2
564MHz
572MHz
580MHz
588MHz
596MHz
604MHz
carrier rest frequency
(580MHz)
(a) Full bandwidth (d.s.b.) f.m. signal
(588MHz)
(572MHz)
(596MHz)
frequencies occupied by interfering (f.m.) signal
N-2
N-1
N
N+1
N+2
(580MHz)
(b) Narrow-band (v.s.b.) f.m. signal with same carrier rest frequency as d.s.b. signal
(588MHz)
(572MHz)
(596MHz)
lower sidebands retained
(580MHz)
(588MHz)
(572MHz)
(596MHz)
upper sidebands retained
frequencies occupied by interfering (f.m.) signal
N-2
N-1
N
N+1
N+2
(570MHz)
(586MHz)
(602MHz)
(c) Narrow-band (v.s.b.) f.m. signal occupying one 8MHz channel
(578MHz)
(594MHz)
lower sidebands retained
(566MHz)
(582MHz)
(598MHz)
upper sidebands retained
(574MHz)
(590MHz)
frequencies occupied by interfering (f.m.) signal

Fig. 9 - Diagram illustrating the tuning of the interfering (f.m.) signal relative to the wanted (a.m.) signal in channel N

channels (i.e. with the carrier rest frequency at the channel edge).

Fig. 9 shows diagrammatically the tuning of the interfering signal relative to the wanted signal. The wanted signal was kept at the same frequency for these tests.

Signal-to-noise ratios were measured at the output of the 6 MHz sound demodulator in the receiver, and the noise level of the sound channel were noted. Noise level on the unmodulated sound channel was 44 dB below the peak modulation level of ±50 kHz deviation.

The results obtained from these tests are presented in Figs. 10 and 11. It should be noted that for clarity in presenting the results, the interfering f.m. signal has been shown at a fixed frequency for each test and the wanted a.m. signal is shown tuned to the various channels (N – 1, N, N + 1, etc). Comparison with the earlier results (where the f.m. signal was the wanted signal) is facilitated by this method of presentation, also.

3.3. Discussion of results

Reducing the bandwidth of the interfering f.m. signal from 16 MHz to 8 MHz, whilst retaining the carrier rest frequency at the edge of channel N and channel N + 1, did not give significantly greater protection to a.m. television picture signals in the adjacent channels N – 1 and N + 1 when the lower sidebands were retained. In the third

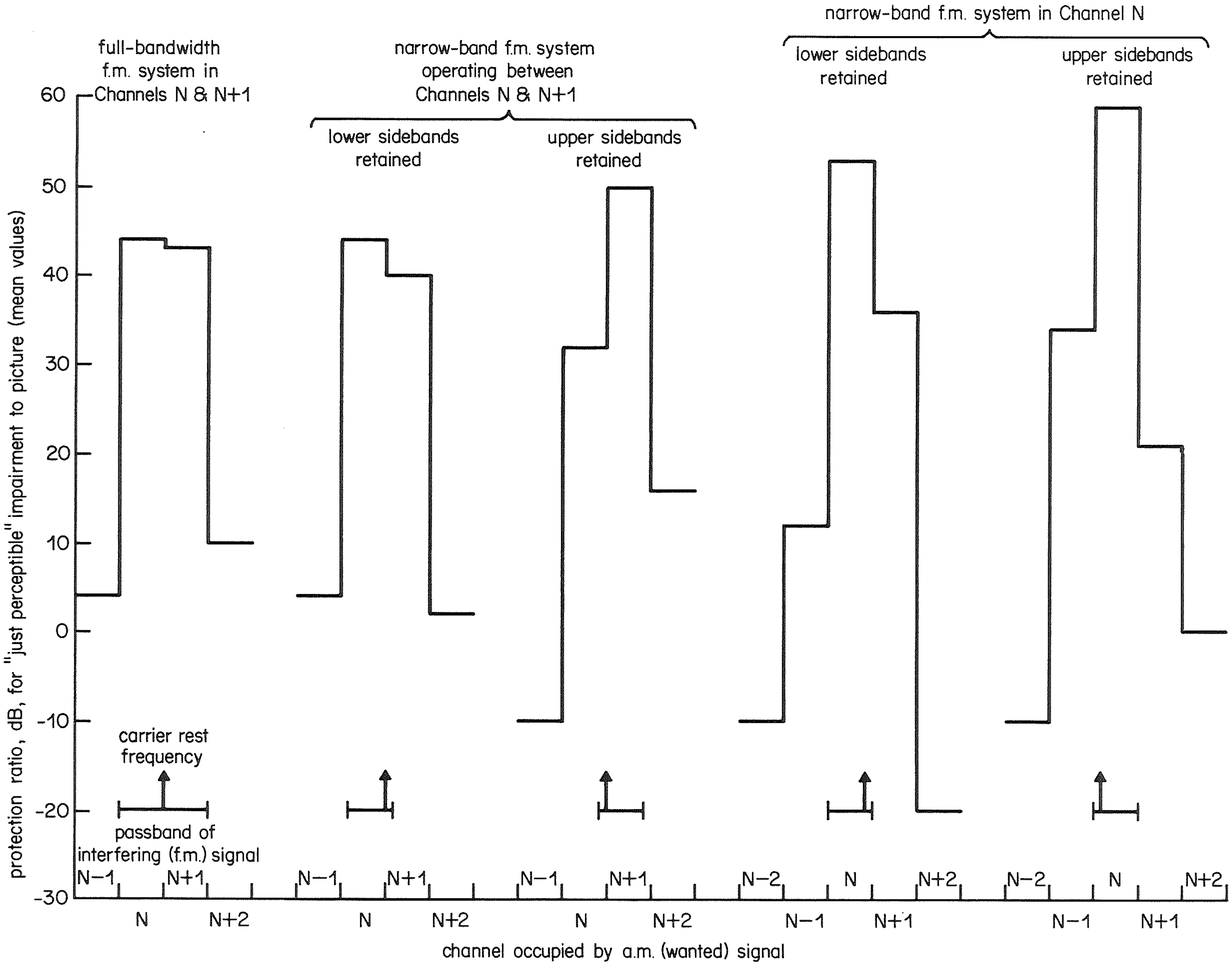

Fig. 10 - Protection ratios for System I a.m. television (vision) signal with interference from an f.m. television signal

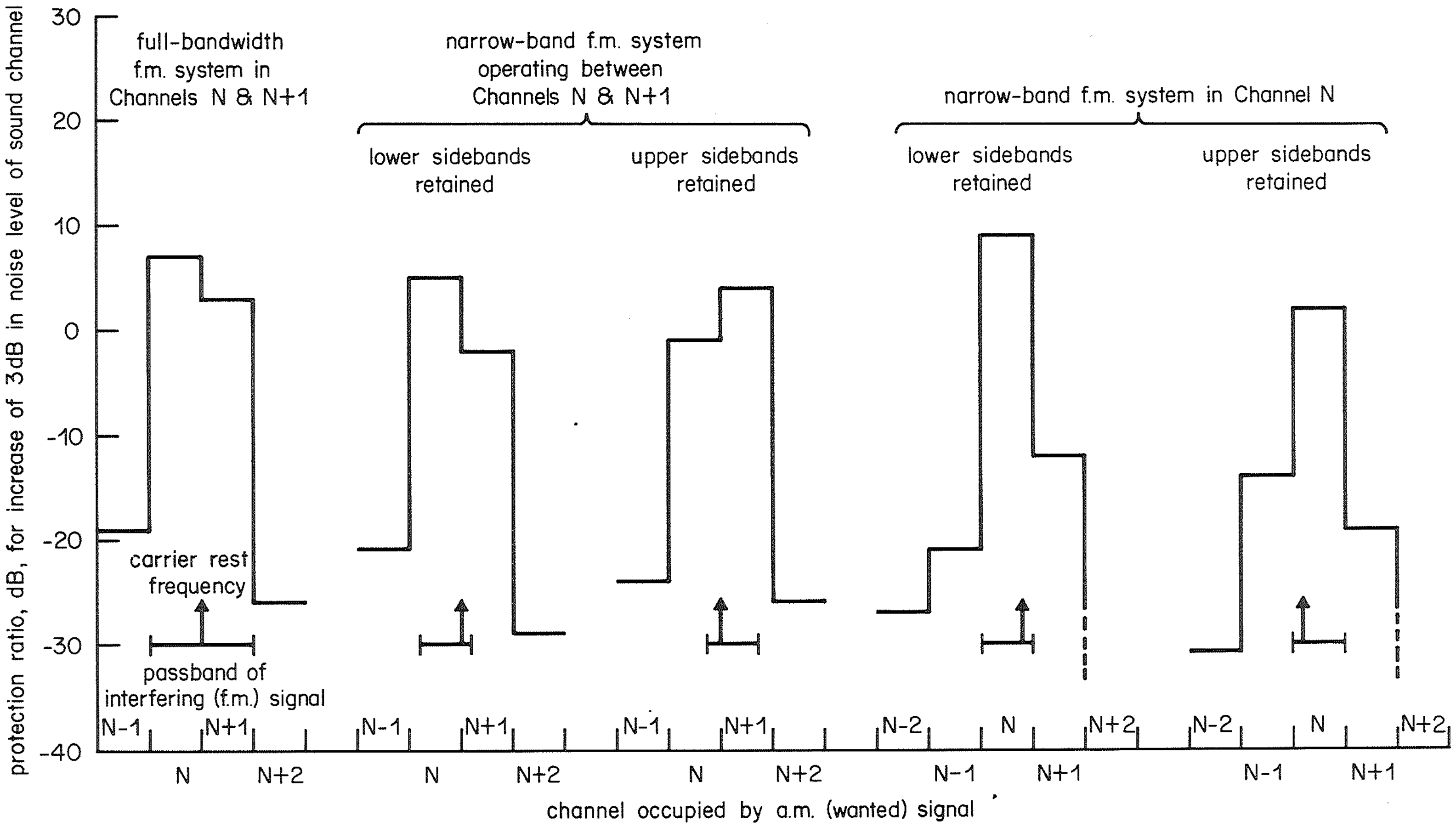

Fig. 11 - Protection ratios for the sound channel of a System I a.m. television signal with interference from an f.m. television signal

case shown in Fig. 10 (where the upper sidebands have been retained, and the lower sidebands suppressed) there was a significant increase in susceptibility to interference when the wanted a.m. signal was in the channel N + 1 or N + 2.

Results for the fourth and fifth tests, in which the v.s.b./f.m. signal was contained within one channel, show that co-channel interference increases substantially with this arrangement without offering any useful benefit as far as adjacent-channel interference is concerned.

In only one test did the presence or absence of the 6 MHz sound subcarrier on the interfering f.m. signal make any difference to the results. When the interfering signal was d.s.b. (occupying channels N and N + 1), the protection ratio for "just perceptible" interference to a.m. reception in channel N − 1 dropped by 10 dB to − 14 dB when the sound subcarrier was removed.

In the tests where the noise level in the receiver sound channel was measured, once again the presence of a sound subcarrier made no difference to most results. Where a difference in protection ratio was recorded it was very small – only 1 to 2 dB. In all tests, protection ratios for the sound channel were substantially lower than those obtained in the tests where picture impairment was studied, indicating a higher degree of immunity to interference in the sound channel relative to the vision channel, for a.m. reception.

The results presented in Fig, 10 show that the only narrow-band f.m. system which is likely to offer any consistent advantages over the full-bandwidth system as far as interference to a.m. television is concerned is the one in which the carrier-rest frequency is on the edge of a u.h.f. channel, and the lower sidebands are retained. It does not appear that the advantages will be very great, from these results.

4. Conclusions

A number of tests conducted to determine the susceptibility of f.m. television signals to interference from System I a.m. television broadcasts, and the susceptibility of System I a.m. television broadcasts to interference from f.m. television signals have shown that mutual interference between signals in adjacent-channels is reduced if the passband of the f.m. signals is reduced from 16 MHz to 8 MHz. The tests have also shown that, in general, it is preferable that the carrier rest frequency remains at the edge of a u.h.f. channel so that the v.s.b. or narrow-band f.m. signal operates within two u.h.f. channels rather than arranging for the signal to occupy exactly one channel. Better results are obtained if the system is of the type which retains most of the lower sidebands whilst suppressing the upper sidebands.

One interesting possibility which presents itself is that an f.m. link could be operated with a full-bandwidth (d.s.b.) transmitter, and the receiver could offer the option of narrow-band (v.s.b.) operation or full-bandwidth (d.s.b.) operation dependent upon whether trouble was being experienced with interference from a broadcasting service in an adjacent channel. This would not offer any reduction of interference to a.m. broadcast reception (in any case, the reduction obtained using a narrow-band transmitter is likely to be slight) but it would give a more versatile link receiving installation with the narrow-band facility available for use in situations where this may offer an advantage.

It should be noted that the sensitivity of the link to co-channel interference from a.m. broadcast signals is slightly greater for narrow-band (v.s.b.) operation. There could, therefore, be circumstances under which the v.s.b. system would be more sensitive to interference from u.h.f. broadcasting stations.

The subjective assessments of picture quality which were carried out as part of this work relied upon the judgement of only two people. It is normal for subjective tests to employ many more observers, and for tests to be conducted under quite carefully defined conditions for results to be valid as measurements of absolute performance. Nevertheless, although the results should not be interpreted as indicating the absolute values of protection ratio with accuracy it is felt that their use for comparing the d.s.b. and various v.s.b. systems on the basis of "just perceptible" interference to the picture is justified. Certain of the tests were repeated at random, and results were verified with an accuracy of 1 or 2 dB.

5. Reference

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